Evolution of early Earth's atmosphere depending on interior volatile depletion and outgassing

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Abstract

From the geological rock record, we have almost no information with respect to early Earth's atmosphere. The composition and the atmospheric pressure during Hadean Earth is hidden from us, and we have only few boundary conditions (such as existence of liquid water during Hadean Earth, upper proposed pressure limits during Archean Earth, and erosion limits due to noble gas composition that we measure today). This information therefore needs to be complemented by modelling data, relating the chemistry and thermal evolution in the interior to melting processes and volcanic outgassing.
In this project, we coupled a 2D mantle convection code with a gas speciation model to infer the influence of the redox state on the composition and amount of outgassed volatiles during the first Gyr of Earth's evolution. The redox state of the silicate rock influences the partitioning of H2O and CO32-into the melt at local temperature and pressure conditions. Extrusive volcanism transports the melt to the surface with the volatiles dissolved in the magma, followed by gas exsolution during magma ascentand degassing at the surface depending on the magma temperature and atmospheric pressure. Intrusive melting depends on the lithostatic pressure of the overlying rocks, the local temperature, melt composition and volatile amounts in the melt.

We infer here the ratio of degassing of H2O, H2, CO2and CO (CH4is not stable under our investigated conditions and O2outgassing is negligible) for different redox state evolution scenarios from the end of the magma ocean to the Archean as proposed in the literature. We infer the variations with respect to outgassed partial pressures of the atmosphere, which will serve as input for climate studies and volatile recycling models for Hadean and Archean Earth. The outgassing results are furthermore of high interest to the Astrobiology community to estimate under which conditions and how long a reducing atmosphere may have been possible, while the upper mantle was already becoming more oxidized as seen in the geological record.
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